ROCKS COLLECTED BY W. THESIGER IN OMAN, ARABIA, IN 1946–7

By P. M. GAME

(*With Plate 3*)

SYNOPSIS

Rock specimens collected by Mr. W. Thesiger on the south-west flank of the Hajar range, Oman, Arabia, are the first obtained from this area. They are described and compared with rocks collected by G. M. Lees from the eastern side of the Oman range and with those collected by H. St. J. B. Philby in the west central area of Arabia, 900 miles to the west.

THE purpose of this note is to list the rocks collected by Mr. W. Thesiger during his journey in Oman in 1946–7, to describe the more interesting types, and to compare them, where possible, with the specimens brought back by previous explorers from other Arabian localities.

That portion of Mr. Thesiger's route on which the collection was obtained is shown in the sketch-map (Fig. 1). The specimens are the first recorded from the landward (south-west) flank of the Oman mountain chain, known as the Hajar range, and for this reason considerable interest attaches to them. Since the majority of the specimens could not be obtained *in situ* (access to the range itself being impossible) they do not permit any conclusions on structure and mutual relations; but they provide valuable evidence as to the composition of some of the rock-types of which this most interesting orogenic belt is composed.

For descriptive purposes the collection will be considered in two groups—a southern and a northern. The southern group comprises rocks which do not belong to the Hajar range proper, but which were obtained, mainly *in situ*, along and near the south-east coast in the region of Batin el Mahai. The northern group consists of pebbles collected in the wadis draining the western flank of the Hajar range, 100 to 120 miles west of its crest.

Southern Region

The most interesting rocks from the Batin region are the granites, porphyries, acid tuffs, and rhyolites which appear to form a well-marked acid igneous suite in this area.

Granites

In its non-marginal phase the freshest granite [1][1] is a pink, medium- and even-grained, non-porphyritic granophyric variety with very small ferromagnesian content and a dominant proportion of pink orthoclase, the crystals of which attain a maximum diameter of 0·5 cm. The average grain-size is slightly lower.

[1] Figures in square brackets refer to entries in the rock register of the Department of Mineralogy under B.M. 1947, 369.


FIG. 1
OMAN
showing part of route followed by THESIGER and localities at which collections were made.
PERSIAN GULF
ARABIAN SEA
ARABIAN SEA
HAJAR RANGE
Jebel Akhdar 9,900'
MUSCAT
ROUTE FOLLOWED
Wadi el Ain
Wadi Aswad
Wadi Ameiri
Wadi Ghaba
Jebel Salakh
Edge of Sand Desert
El Hagaf
Batin el Mahai
SALALAH
NEOLITHIC JADE AXE-HEADS FOUND HERE BY W.THESIGER
⊙ - localities of collections
0 50 100 150 200
scale of miles
54°
56°
58°
60° E
24°N
22°
20°
18°
Drawn by R.T.W. Arkins

A thin section of this rock (Pl. 3, Fig. 1) shows a beautifully developed micrographic intergrowth of quartz and orthoclase, which makes up probably 80 per cent. of the whole rock. Very little quartz or feldspar occurs not intergrown. There is a small proportion of acid plagioclase and some patches of decomposed biotite. An aplitic phase of this granite contains a considerable plagioclase content and the quartz shows marked undulose extinction.

A somewhat decomposed variety [2] from the southern edge of el Hagaf has a pale brownish-cream colour and a considerable plagioclase content. This specimen does not show a quartz-feldspar intergrowth. Microcline is subordinate to orthoclase, but forms relatively large grains. Biotite is sparse, but mostly unaltered. Several small, decomposed specimens from the same region resemble the pink variety described above, but show a considerable biotite content.

Microgranites

The first specimen [4] is brick-red to purplish in colour, compact, fine-grained with small sparse phenocrysts of pink feldspar. The thin section shows rare phenocrysts of acid plagioclase and orthoclase—both kaolinized—in a microcrystalline base of quartz and feldspar—the latter kaolinized and haematite-stained. Ferromagnesian minerals are absent. Iron-ore granules show a fairly even distribution. This may be a marginal phase of the granite represented by [1].

The second microgranite [3] is salmon-coloured and contains quartz phenocrysts in addition to those of feldspar (sodic plagioclase and orthoclase). The proportion of phenocrysts is much greater than in the first type.

Feldspar-porphyry [7]

This is a dull olive-green rock with conspicuous white idiomorphic feldspar phenocrysts.

The thin section shows that these phenocrysts are extensively altered and corroded. Some, however, can be still recognized as sodic plagioclase; the more altered crystals are probably potash-feldspar. Biotite also forms sparse phenocrysts, one of which is 2·5 cm. long. The microcrystalline base consists of quartz and feldspar with a considerable development of hornblende.

Acid tuff [6]

In hand-specimen this resembles a porphyry with abundant phenocrysts of orthoclase and quartz averaging 2 mm. in diameter in a dull-purplish groundmass. The thin section (Pl. 3, Fig. 2) shows, however, a well-developed vitroclastic structure in the dominantly glassy base. Most of the orthoclase crystals are heavily impregnated with haematite. The crystals have undergone some corrosion before ejection.

Rhyolite [8]

The typical variety is a highly siliceous brownish-grey rock showing, megascopically, well-developed banding. The section (Pl. 3, Fig. 3) shows this type to be devoid of phenocrysts and to be composed of a microcrystalline quartz-feldspar aggregate. The flow-structure is expressed by dusty, semi-opaque shreds of secondary, kaolinized material. This same material also occurs as a replacement product in the form of

sporadic spherules 0·5 mm. in diameter with radiating, fibrous structure. A second rhyolite is black in colour and shows very fine bands. A third type varies from dove-grey to purple, is exceedingly hard and dense, and has undergone secondary silicification.

In addition to the above types, the igneous rocks from this region include a uralitized gabbro [19], which appears to have suffered mechanical deformation, and an epidiorite [21] possibly derived from a basic dyke-rock.

The sedimentary rocks from this southern area consist of sandstones and limestones, for which a Lower Miocene age is suggested by Mr. Thesiger's discovery in the same district of an oyster bed containing the species *Ostrea latimarginata* Vredenburg. The remainder of the sedimentary rocks, however, contain no fossils.

The sandstones comprise a white fissile variety [25], cemented by salt (halite) and calcium carbonate, a pale-pink type [24], and a soft friable species [16] containing glauconite.

Most of the limestones are sandy, in greater or lesser degree; they vary in colour from fawn, through drab to dark grey, and show no features of special interest.

Northern Region

The most interesting find in this area is a fragment of black jade (nephrite) [41] collected from the bed of the Wadi el Ain; this fragment has the form of a flat, water-worn pebble, roughly trapezium-shaped, measuring 5 cm. along the longest edge. It is a tough, dense, greenish-black, finely crystalline rock with somewhat hackly fracture. Microscopic examination (Pl. 3, Fig. 4) shows it to consist of a felted mass of randomly oriented, faintly pleochroic tremolite-actinolite fibres, averaging 0·1 mm. in length, with more coarsely crystalline areas in which the length of the fibres ranges from 0·2 to 0·5 mm. A few porphyroblasts of the same amphibole (some twinned) attain a length of 1 mm. The only other constituent is magnetite, which is confined to the coarser grained patches, where it occurs as well-formed crystals, 0·1 mm. in diameter.

The occurrence of this specimen in the Wadi el Ain is clear evidence of its derivation from some source in the Hajar range, though the precise location remains to be found. In view of the discovery by Thesiger in 1946 of two neolithic green jade axe-heads near Salalah, on the Arabian sea coast, this subsequent find of a similar rock type is of particular interest. In order to examine the degree of similarity between the Oman nephrite and the nephrite used for the artifacts, specific gravity determinations and optical tests were made and thin sections examined (the two axe-heads having been kindly lent by the Trustees of the British Museum for this purpose). The results obtained are shown in the table on p. 19.

These differences and the colour difference are too great to postulate identity of origin. It is more than likely that the two axe-heads were imported. The occurrence of another variety of nephrite in the same region is certainly a strange coincidence.

In the bed of the Wadi Ameiri, south of Wadi el Ain, Mr. Thesiger collected a pebble of a gabbro [30] of an interesting and somewhat unusual type (Pl. 3, Fig. 5). It consists solely of plagioclase (bytownite-anorthite) and diopside with schiller inclusions. The grain-size is very even, averaging about 1 mm. The simple mosaic texture

(reminiscent of that of some allivalites from Rum [B.M. 47575, 47576]) indicates simultaneous crystallization of the two constituent minerals. The proportion of feldspar is slightly greater than that of pyroxene.

Specimen	*Locality*	*Sp. gr.*	*R.I.*	*Extinction angle*	*Other components (additional to nephrite)*
Axe-head B.M. 1947, 10.3.1	Ummdhul Spring NE. of Salalah, SE. Arabia	2·990	1·632	14½°	Small equi-dimensional grains of an unidentified colourless mineral; sporadically distributed.
Axe-head B.M. 1947, 10.3.2	Coastal plain of Jerbib, 6 miles W. of Salalah	2·981	1·630	16°	Nil.
Nephrite pebble B.M. (Nat. Hist.) 1947, 369, 41	Wadi el Ain, Oman	3·049*	1·651	19°	Small grains of magnetite (confined to patches of coarser crystallinity).

* Relatively higher sp. gr. due, in part, to the magnetite content.

A further find in the same wadi (Wadi Ameiri) was a small pebble of anorthosite [28], coarsely crystalline, consisting essentially of bytownite-anorthite, with a subordinate proportion of hypersthene. Anorthosites are often associated with pre-Cambrian 'shields' but have not so far been recorded from the ancient crystalline rocks of Arabia.

The collections from both Wadi Ameiri and Wadi el Ain include several rhyolite pebbles [32]. These vary greatly in colour, from very dark-grey, through dull-purple, light-brown, and light-grey to cream-coloured. They mostly show fairly conspicuous banding and an absence of phenocrysts.

The most interesting sedimentary rock from this area is a dull, olive-green, siliceous radiolarian chert [31] which, in thin section (Pl. 3, Fig. 6), is seen to be cryptocrystalline and to show evidence by banding of original bedding. The tests of the original radiolaria have been replaced by radiating, fibrous chalcedony, which forms mutually interfering aggregates. These are packed together to form spherulites averaging 0·2 mm. in diameter (largest 0·3 mm.). A fairly close match for this rock is a radiolarian chert from the Oligocene 'green beds' of the Elburz mountains, north-east of Tehran. This rock [B.M. 1947, 406, 7] shows in thin section similar, though slightly smaller, spherulites (average diameter 0·15 mm.) also infilled by fibrous, radiate aggregates of chalcedony. It has been described by Sir Edward Bailey[1] as a 'rather dirty, cryptocrystalline siliceous chert including many radiolaria'. The latter have been identified by Mr. A. G. Davis as a species of *Cenosphaera*.

Other representatives of the sediments of the northern region are mainly calcareous; there are no true sandstones. The limestones include a characteristic black variety [33] with some calcite veining and traces of organic structures. Other varieties are pale-grey, cream-coloured, and yellowish-brown. The majority show etched surfaces (Rillensteine). The collection also includes a small pebble of a straw-coloured oolitic limestone [43]. The nearest possible 'match' for this is a pink oolitic Miocene lime-

[1] Bailey, E. B., Jones, R. C. B., and Asfia, S. 1948. Notes on the geology of the Elburz Mountains, north-east of Tehran, Iran, *Quart. J. Geol. Soc. London*, **104**: 13–14.

stone with small shells and foraminifera, brought back by Mr. H. St. J. B. Philby from Jaub Anbak, at the base of the Qatar peninsula [B.M. 1932, 1175, 24]; the oolites in the latter are three to four times as large as those in the Oman specimen.

The collection of pebbles from Wadi Ameiri also includes some calcareous breccias and conglomerates. One type [35] contains subangular pebbles of a pink, calcareous sandstone, 6 mm. or less in diameter. In the other main type the pebbles are mainly dark-coloured, hard, silicified rocks such as cherts and rhyolites; they are subangular and the largest are about 2·5 cm. in diameter.

It is of interest to compare briefly the rocks collected by Thesiger with those brought back by previous Arabian explorers. On the eastern (i.e. coastal) side of the Oman range Dr. G. M. Lees[1] found a variety of igneous rocks (mainly serpentine, gabbros, diorites, and alkali-basalts) which he grouped under the heading of the Semail igneous series; these, he considered, formed a great thrust-sheet, overriding an intensely crushed and contorted incompetent sedimentary series (the Hawasina series) containing massive lavas and minor intrusives (mainly keratophyres, sheared tuffs, and melaphyric basalts). It is difficult to match these types with those collected by Thesiger; the latter, moreover, do not show evidence of the strong shearing movements characteristically developed in the Semail igneous series. However, the pale-grey and blue-grey limestone pebbles from the Wadis Ameiri and el Ain may possibly be correlated with Lees's Musandam limestone (Jurassic to Lower Cretaceous) in which massive beds of this colour were recorded in a measured section. In the absence of palaeontological evidence, no more precise statement can be made.

The acid igneous rocks collected by Thesiger in the southern part of the province show general similarity to corresponding types encountered by H. St. J. B. Philby in the west central area of Arabia, 900 miles to the west. The correspondence is closest in the granites. In both regions the characteristic type is a pink to cream-coloured, leucocratic, fine- to medium-grained, non-porphyritic type with or without biotite and devoid of any gneissic banding. Thesiger's pink granophyric type from Batin el Mahai [1] finds its counterpart in a red graphic granite collected by Philby from Bani Shauhata [B.M. 1932, 1175, 97]. The rhyolites from both regions also show general similarities. The banded varieties found near Wadi Ranya and Raudhat ibn Ghannam in the west resemble rhyolites from Batin el Mahai in southern Oman, though the spherulitic structure seen in some of the latter is absent in the former.

The porphyries, which are fairly plentiful in the collections from the two separate localities, show some differences in detail. The west Arabian types are conspicuous for a noteworthy content of sphene, a mineral not observed in the Oman porphyries. The latter, moreover, contain quartz as phenocrysts, whereas in the corresponding western types quartz is in general only a constituent of the groundmass.

There is nothing in the Oman collection to match the gneisses, schists, and amphibolites which apparently occupy a considerable area in the Najran region, on the south-west fringe of the Rub al Khali. But in view of the necessarily localized character of the Oman collection and the derived nature of much of its material, this evidence of dissimilarity is inconclusive.

[1] Lees, G. M. 1928. The Geology and Tectonics of Oman and of parts of South-Eastern Arabia, *Quart. J. Geol. Soc. London*, **84**: 585–670.

Derivation of the Gravels of Jafura and Rub al Khali

The gravels collected by Philby and Major R. E. Cheesman have been described by W. Campbell Smith.[1,2] Mr. Bertram Thomas has also collected samples of pebbles from these extensive plains.

The commonest type of pebble is rhyolite—usually a dark-coloured, highly siliceous variety, generally banded, but without phenocrysts; an olive-green, dense aphanitic variety with no visible flow-structure is also abundant. After rhyolites, the pebbles most commonly found are porphyries, limestones, and pink or red granites—all types occurring in Oman as well as in the central west zone. From the correspondence with the rocks of the latter area Campbell Smith was led to infer a westerly origin for the gravels; at that time (1932) there was no opportunity for study of the rock types from west Oman. Those now brought back by Thesiger show that an easterly origin is also a possibility, and one which receives some support from the trend of the present drainage from the Oman mountain range which is to the south-west. It may well be that both east and west have contributed their quota of hard resistant rocks to these great gravel plains of the interior.

I wish to thank Dr. W. Campbell Smith for much helpful advice and criticism. I am also grateful to Mr. R. T. W. Atkins for preparing the map and to Mr. D. L. Williams for taking the photomicrographs.

APPENDIX

Catalogue of Specimens of Rocks from Oman collected by Mr. W. Thesiger, topographically arranged

Locality	*See page*	*Entry in Mineral Department Register*	*Specimens collected*
Southern Area			
Batin el Mahai	15	1947, 369 (1)	Granite; pink; medium-grained, non-porphyritic; fresh.
	17	,, ,, (2)	Granite; weathered; biotite-rich type.
	17	,, ,, (3) & (4)	Microgranites; purple (4) and salmon-coloured (3).
	17	,, ,, (5)	Aplite.
	17	,, ,, (6)	Acid tuff; dull purple.
	17	,, ,, (7)	Feldspar-porphyry; dull olive-green.
	17	,, ,, (8)	Rhyolite; grey; banded.
	—	,, ,, (9)	Limestone; grey-brown.
	—	,, ,, (11)	Grey marl.
	—	,, ,, (12)	Quartzite; pale grey.
	—	,, ,, (13)	Calcite rhomb.
	—	,, ,, (14)	Calcite, coarsely fibrous.
	—	,, ,, (15)	Chalcedony.
	18	,, ,, (16)	Sandstone; grey to brick-red; soft, loosely cemented; contains glauconite.
	—	,, ,, (17)	Iron pan crusts.

[1] Philby, H. St. J. B. 1933. *The Empty Quarter*, London, Appendix B: 376–379.
[2] Cheesman, R. E. 1926. *In Unknown Arabia*, London, Appendix 7: 422–426.

Locality	*See page*	*Entry in Mineral Department Register*	*Specimens collected*
SOUTHERN AREA (*cont.*)			
el Hagaf (southern edge)	—	1947, 369 (18)	Biotite-granite; pale-brown to cream-coloured; medium-grained.
	18	,, ,, (19)	Gabbro; uralitized.
	—	,, ,, (20)	Rhyolite; black; banded.
	18	,, ,, (21)	Epidiorite.
	—	,, ,, (22)	Rhyolite; pale-green to chocolate-brown; dense silicified type; subconchoidal fracture.
	—	,, ,, (23)	Limestones; grey-brown and cream-coloured.
	—	,, ,, (24)	Sandstone; pale-pink; friable.
	18	,, ,, (25)	Sandstone; cream-coloured; fissile; cemented by a calcareous matrix containing salt (halite).
	—	,, ,, (26)	Jasperoid quartz.
	—	,, ,, (27)	Iron pan.
NORTHERN AREA			
Wadi Ameiri	19	,, ,, (28)	Anorthosite.
	—	,, ,, (29)	Gabbro (?) fine-grained; partly decomposed.
	18–19	,, ,, (30)	Gabbro, consisting of plagioclase and diopside.
	19	,, ,, (31)	Radiolarian chert; dull olive-green; very dense; subconchoidal fracture; silicified; banded.
	19	,, ,, (32)	Rhyolites; cream-coloured; pale-grey and dark-grey; banded; silicified types.
	19	,, ,, (33)	Limestones; blue-grey; 'Rillensteine'.
	—	,, ,, (34)	Limestone; pale grey-green variety.
	20	,, ,, (35)	Sandstones; conglomeratic, with pink, sandy limestone pebbles up to 6 mm. diameter; calcareous cement; also gritty sandstones.
	—	,, ,, (36)	Quartz and jasper.
	—	,, ,, (37)	Gypsum (selenite).
Wadi el Ain	—	,, ,, (38)	Altered olivine-gabbro (?).
	—	,, ,, (39)	Quartz-porphyry; purple, with conspicuous white feldspars.
	—	,, ,, (40)	Rhyolites; dark brownish-grey; light brown; dull purple and cream-coloured; silicified.
	18–19	,, ,, (41)	Nephrite; black; dense; fine-grained.
	—	,, ,, (42)	Limestones; dark-coloured; buff-coloured; very pale-grey and white; 'Rillensteine'.
	19–20	,, ,, (43)	Oolitic limestone; straw-coloured.
	—	,, ,, (45)	Jasper.
Wadi Ghaba	—	,, ,, (46)	Sandstone; ferruginous.
	—	,, ,, (47)	Rhyolites; grey; pale-green and dark-green; silicified; banded.

PLATE 3

FIG. 1. Granophyric granite [1] showing well-developed micrographic intergrowth of quartz and orthoclase. From Batin el Mahai. Crossed nicols. ×30. (See p. 17.)

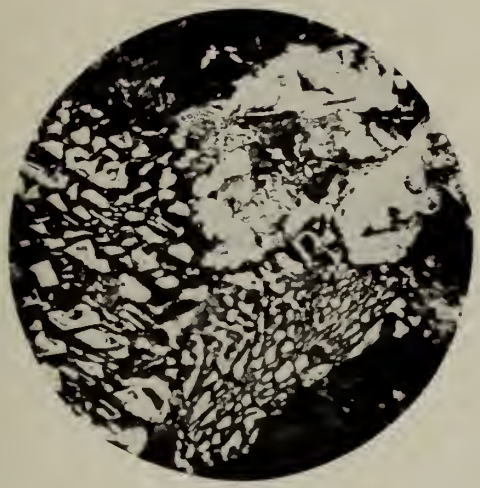
FIG. 2. Acid tuff [6] showing vitroclastic structure and a crystal of quartz at the margin. From Batin el Mahai. Ordinary light. ×90. (See p. 17.)

FIG. 3. Rhyolite [8]. From Batin el Mahai. Ordinary light. ×20. (See p. 17.)

FIG. 4. Nephrite [41] showing randomly oriented tremolite-actinolite fibres. From Wadi el Ain. Crossed nicols. ×160. (See pp. 18–19.)

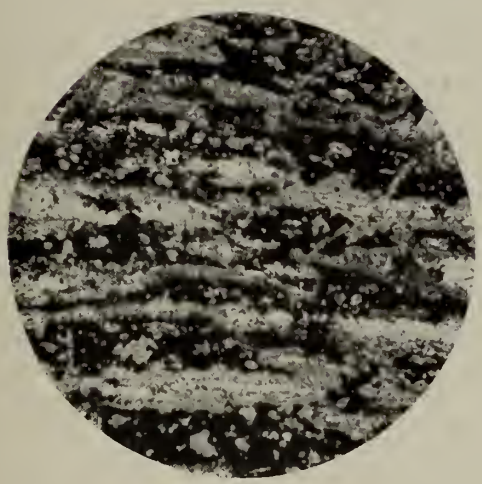
FIG. 5. Gabbro [30] consisting of plagioclase and diopside showing schiller inclusions. From Wadi Ameiri. Crossed nicols. ×20. (See pp. 18–19.)

FIG. 6. Siliceous chert [31] showing sections of spherules containing radiating, fibrous chalcedony replacing original radiolaria. From Wadi Ameiri. Ordinary light. ×20. (See p. 19.)



1

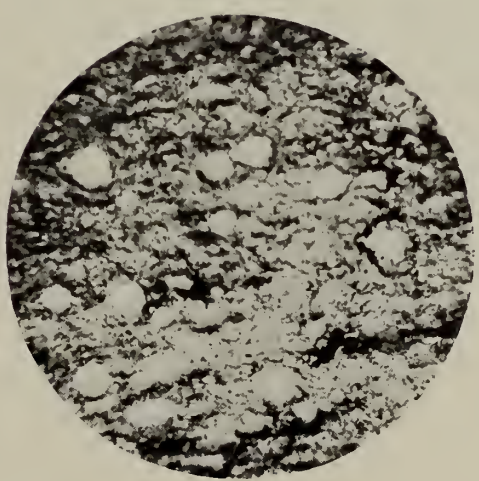
2



3

4

5



6

ROCKS FROM OMAN, ARABIA